(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 456 716 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
11.03.1998 Bulletin 1998/11

(21) Application number: **90902878.9**

(22) Date of filing: **17.01.1990**

(51) Int. Cl.^{6}: **A61B 5/00**

(86) International application number:
PCT/US90/00394

(87) International publication number:
WO 90/07905 (26.07.1990 Gazette 1990/17)

(54) NON-INVASIVE MEASUREMENT OF BLOOD GLUCOSE

NICHT-INVASIVE MESSUNG DER GLUKOSE IM BLUT

MESURE NON INVASIVE DE LA GLYCEMIE

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB IT LI LU NL SE

(30) Priority: **19.01.1989 US 298904**

(43) Date of publication of application:
21.11.1991 Bulletin 1991/47

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Description

Field of the Invention

This invention relates to instruments and methods for the non-invasive quantitative measurement of blood glucose. More particularly, the invention relates to such quantitative measurement via near-infrared interactance and transmittance.

Background of the Invention

Information concerning the chemical composition of blood is widely used to assess the health characteristics of both people and animals. Blood analysis provides an indication of the current status of metabolism (e.g. glucose content) as well as level of risk associated with certain major illnesses (e.g. risk of cardio-vascular disease as a function of cholesterol level). Blood analysis, by the detection of above or below normal levels of various substances also provides direct indication of the presence of many types of diseases and dysfunctions.

The normal method of determining blood chemistry is by removing a sample of blood (e.g. 5-10 ml) and performing one or more standard chemical tests. These types of tests are moderately expensive, require one class of trained technicians to remove the blood and another class of trained technicians to perform the chemical tests. Moreover, the results of the blood tests often are not available for several hours, and sometimes even several days.

Recently, an alternative type of technology (i.e. self-contained instruments) has been introduced for relatively rapid blood screening of a large number of subjects. These instruments, in general, use a much smaller blood sample (approximately .25 ml) from a "finger poke." This small blood sample is placed on a chemically-treated carrier and entered into the instrument. These instruments normally provide either an individual analyses (e.g. glucose level) or multiple analysis in a few moments. These types of instruments unfortunately are quite costly, e.g., in the range of several thousand dollars.

A third class of blood instrumentation is available for the specific purpose of determining glucose level in people with diabetes. This technology also uses a small sample from a finger poke and the sample is placed on a chemically treated carrier which is inserted into a portable battery operated instrument. In general, these instruments provide a single function; i.e. measurement of glucose. Although these specialized instruments are relatively low cost ($300 or less is typical), the cost of the disposable carrier "stick" must be considered. Since some diabetic patients may require glucose analysis four or more times a day, the cost over a period of a year can become significant.

Current glucose analytical systems require blood to be extracted from the body prior to performing the analysis. This blood withdrawal requirement limits the application of such testing; many people who may be interested in knowing their glucose level are reluctant to have either their finger poked or blood samples removed by hypodermic needle. This reluctance or anxiety in allowing blood sample removal is due to concern over the possibility of infection, discomfort (pain) and generalized patient fear.

Thus, there is a great need for non-invasive analytical instruments and methods that would provide essentially the same accuracy as conventional blood glucose tests. Moreover, there is a need for a non-invasive low-cost method for measurement of glucose in diabetic patients.

Near-infrared (sometimes referred to herein as simply "near-IR") quantitative analysis is widely used in the field of agriculture for determining chemical compositions within grain, oilseeds, and other agricultural products. As an example, near-IR energy reflected from the surface of finely ground seeds and grain provides information concerning protein and moisture content. For a general introduction to near infrared quantitative analysis, see "An Introduction to Near-Infrared Quantitative Analysis" presented by Robert D. Rosenthal at the 1977 Annual Meeting of American Association of Cereal Chemists. Near-infrared technology has been extended to allow totally non-destructive measurements by using light transmission through a sample as discussed in "Characteristics of Non-Destructive Near-Infrared Instruments for Grain and Food Products" by Robert D. Rosenthal, presented at the 1986 Meeting at the Japan Food Science Institute. Although this transmission approach avoids the need to finely grind the sample, it is not suited for use where access to two opposite surfaces is not available.

One example of this transmission approach is provided in U. S. Patent No. 4,621,643 (New, Jr. et al., 1986) relates to an optical oximeter apparatus for determining pulse rate and degree of arterial oxygen saturation. Light energy is passed through an appendage of the body, e.g. a finger, and strikes a detector positioned on a side of the appendage opposite from the light source. Pulse rate and saturated oxygen are calculated from coefficients of extinction of light at the selected wavelengths.

Another approach to near-infrared quantitative analysis, using near-infrared interactance, was developed for non-invasively measuring body fat content. This approach is described in "A New Approach for the Estimation of Body Composition: Infrared Interactance", Joan M. Conway et al., The American Journal of Clinical Nutrition, 40: Dec. 1984, pages 1123-1230. In this non-invasive technique, a small optical probe that allows optical energy to enter the arm is placed on the biceps. The percent body fat of the entire body is determined by measuring the spectrum change of the energy returned from an area adjacent the light entry point.

Document EP-A-0 160 768 discloses an apparatus

and a method as defined, respectively, in the preambles of claims 1 and 17.

In accordance with the present invention, a near-infrared quantitative analysis instrument for non-invasive measurement of blood glucose in blood present in a body part of a subject, comprising: (a) means for introducing near-infrared energy into blood present in a body part of a subject; (b) a near-infrared detector for detecting near-infrared energy emerging from the body part and for providing a signal upon detection of near-infrared energy emerging from the body part; (c) means for positioning both the near-infrared introducing means and the near-infrared detector closely adjacent to the body part so that near-infrared energy detected by the detector corresponds to blood glucose level in said body part; and (d) means for processing the signal produced by the detector into a second signal indicative of the quantity of glucose present in the blood of the subject; characterised in that the near-infrared detector is arranged to detect infrared energy emerging from the body part said near-infrared energy comprising a plurality of wavelength pairs within the range of about 600 to 1100 nanometers, said plurality of wavelength pairs being centred on the same wavelength.

The present invention also provides a non-invasive method for quantitatively analyzing blood glucose in blood of -a subject, comprising: (a) introducing near-infrared energy into blood within a body part of the subject; (b) detecting near-infrared energy emerging from the subject with a detector which provides a signal upon detecting said energy emerging from the subject; and (c) processing the signal to provide a second signal indicative of the amount of glucose present in the blood of the subject; characterized in that a plurality of pairs of wavelengths of near-infrared energy within the range of about 600 to 1100 nm are detected by said detector, said plurality of pairs of wavelengths being centered on the same wavelength.

Some of these inventive methods utilize the principal of near-IR transmission while others utilize the principal of near-IR interactance.

In accordance with one aspect of the present invention, a near-infrared quantitative analysis instrument for measuring blood glucose comprises means for introducing near-IR energy into blood present in a blood vessel, means for detecting near-IR energy following interactance of the same with the blood, and means for positioning the introducing means and detecting means over a blood vessel of the subject.

This aspect of the invention further relates to methods wherein near-IR energy is introduced into a vein or artery of a subject and interacts with blood glucose, the near-IR energy emerging from the subject is detected by a detector which provides an electrical signal, and the signal is processed to provide a readout indicative of the amount of glucose in the blood.

This aspect of the invention also relates to means and methods for marking a position over a vein or artery of a subject and then aligning a near-IR analysis instrument with the markings to accurately position the instrument.

Another aspect of the invention relates to an apparatus for measuring blood glucose via near-IR transmission through a blood-containing body part, the apparatus including means for introducing near-IR energy into one side of a body part, means for detecting near-IR energy emerging from an opposite side of the body part and means for positioning the near-IR introducing and detecting means on opposite sides of the body part.

This aspect of the invention also relates to methods for measuring blood glucose via near-IR transmission including the steps of introducing near-IR energy into one side of a blood-containing body part, detecting near-IR energy emerging from an opposite side of the body part and calculating blood glucose content.

Brief Description of the Drawings

FIG. 1 is a partially schematic elevational view of a near-infrared quantitative blood analysis instrument to which the present invention pertains.

FIGS. 2A and 2B are partially schematic elevational views of alternate embodiments of near-infrared quantitative analysis instruments.

FIG. 3 is an elevational view of a location device for use with the instrument shown in FIG. 1.

FIG. 4 illustrates one embodiment for practicing the inventive method.

FIGS. 5A and 5B illustrate two known configurations for interposing filters in a light path.

FIG. 6 is a plot of log (1/I) versus wavelength.

FIG. 7 illustrates a wavelength search study via a plot of correlation coefficient versus wavelength.

FIGS. 8 and 9 show plots of midpoint wavelength versus correlation coefficient for first derivative equations.

FIGS. 10 and 11 illustrate plots of correlation coefficient versus wavelength for second derivative equations.

Detailed Description of the Preferred Embodiments

This invention uses the principle of light interactance to measure blood glucose level non-invasively by locating an optical transmitter and a detector on the skin surface near either an artery or vein. Alternatively, the invention uses the principal of light transmission through a portion of the body that has relatively uniform profusion of blood in order to measure non-invasively blood glucose.

In general, the arteries and veins of the human body are buried deep in the body to protect them from possible harm. However, in certain locations of the body, these blood carrying vessels are close to the skin surface. This is particularly true for veins. Some exam-

ples of such locations are at the crease of the elbow, the wrist, the back of the hand, and the bridge of the nose. Since the concentration of glucose is relatively constant in both the veins and arteries, valid measurements can be obtained in either. However, because veins are generally closer to the skin's surface, they usually are the better candidate for non-invasive measurements.

The finger tip is another site particularly well suited for performing blood measurements with near-IR light. The blood supply is distributed within the finger tip and, thus, small variations in the placement of a near-IR emitter or detector will not have a profound effect on the measurement results.

According to one embodiment of the invention utilizing near-IR interactance analysis techniques, near-IR light energy is passed through the skin and connective tissues and into a blood vessel of a subject. A portion of the energy re-emerges from the blood vessel of the test subject and is detected by a detector. Following amplification of the detector-generated signal, the amplified output is processed into an output signal indicating the amount of glucose in the subject's blood. The output signal drives a display device for providing a visual display of blood glucose content.

According to another embodiment of the invention utilizing near-IR transmission analysis techniques, near-IR light energy is transmitted through a blood-containing portion of the body of a test subject. The near-IR energy emerges from the test subject, opposite from the near-IR source, and is detected by a detector. Following amplification of the detector-generated signal, the amplified output is processed into an output signal indicating the amount of glucose in the subject's blood.

In one embodiment utilizing near-IR interactance, the entire analytical instrument, including near-infrared source, transmitter, detector, amplifier, data processing circuitry and readout is contained within a lightweight hand-held unit. Infrared emitting diodes (IREDs) disposed in one chamber of the unit are focused to transmit near-IR energy of preselected wavelengths to, e.g., a prominent vein of the wrist. The near-IR energy interacts with the constituents of the venous blood and is re-emitted from the vein. A detector housed within a second chamber of the unit is disposed along the vein a distance (l) from the emitter and collects this energy. The detected signal is amplified and data processed into a signal indicative of the amount of glucose in the blood. This signal is then fed to a readout device (preferably a digital readout) for recordation by a technician or direct analysis by a physician or the subject himself.

Other near-IR apparatus, such as the optical probe and associated instrumentation described in U.S. Patent No. 4,633,087 (Rosenthal), are useful in the practice of the present methods in which near-IR interactance is used to quantitatively measure blood glucose levels.

A location device may be used which is specially adapted to permit the user to locate the interactance instrument discussed above accurately along a vein. The location device permits the skin to be marked to ensure that repeated measurements are taken from the same location, if desired.

A particularly preferred lightweight, hand-held interactance analysis instrument in accordance with the invention is illustrated in Fig. 1. The instrument 10 includes one or more means for providing at least one point source of near-infrared energy of a predetermined half-power bandwidth centered on a wavelength of interest positioned within a first chamber 30 of the instrument 10. The near-infrared point source means are positioned so that near-infrared energy being emitted from the point source means will be focussed by lens 12 through window 14 and onto the skin of the test subject. The near-infrared point source means may comprise one or a plurality of infrared emitting diodes (IREDs). Two such IREDs 16 are visible in the embodiment illustrated in Fig. 1. In other embodiments employing a plurality of IREDs, three, four or more IREDs may be utilized as the point source means.

In lieu of laborious characterization and sorting of each IRED, we prefer to provide narrow bandpass optical filters (as shown schematically in Fig. 1) between the infrared emitting diodes and the lens 12. A filter 23 is positioned between each IRED and lens 12 for filtering near infrared radiation exiting each IRED and thereby allowing a narrow band of near-infrared radiation of predetermined wavelength to pass through the filter and lens 12. Utilization of narrow bandpass optical filters provides for specific wavelength selection independent of the center wavelengths of the particular infrared emitting diodes being used. Measurements can be taken inside the half power bandwidth of the IREDs, or alternatively, outside the half power bandwidth of the IREDs as disclosed in commonly owned U.S. Patent No. 4,286,327. Figs. 5A and 5B illustrate two known configurations for interposing filters in a light path.

An optical detector, illustrated schematically and designated by reference numeral 28, is disposed within a lower end portion 42 of a second chamber 40 in case 20. Inner wall 22 is positioned between detector 28 and lens 12, thereby providing an optically-isolating mask which prevents near infrared radiation from the point source means and/or lens 12 from impinging directly on detector 28. Optical detector 28 generates an electrical signal when near-infrared radiation is detected.

The optical detector 28 is connected to the input of an electrical signal amplifier 32 by suitable electrical conducting means 33. Amplifier 32 may be an inexpensive integrated circuit (IC) signal amplifier, and amplifies the signals generated when near-IR energy strikes detector 28. The output of amplifier 32 is fed to a data processor and display driver 34 which provides a signal to readout device 36. The readout device 36 may have a digital display for directly displaying the amount of glucose present in the subject's blood.

The embodiment of Fig. 1 includes an optical filter 29 for shielding all but the desired near-IR energy from

detector 28. Filter 29 and window 14 are positioned for direct contact with the skin of the test subject. An optically clear window can be employed in lieu of filter 29, if desired.

As noted earlier, this embodiment of the present invention utilizes the principal of near-IR interactance for quantitative analysis. In interactance, light from a source is shielded by an opaque member from a detector so that only light that has interacted with the subject is detected. Accurate measurements of the concentration of blood glucose can be made using many of the conventional algorithms used in near-IR quantitative analysis including those that have only a single variable term such as the following:

Approximated First Derivative Algorithm

$$C = K_0 + K_1 [\log 1/I_G - \log 1/I_H]$$

Approximated Second Derivative Algorithm

$$C = K_0 + K_1 [\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]$$

Normalized First Derivative Algorithm

$$C = K_0 + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

Normalized Second Derivative Algorithm

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

where the first two of the above equations do not form part of the present invention, and where C denotes concentration of glucose present in the blood, K_0 is the intercept constant, K_1 is the line slope of the variable term, and log 1/I terms are as defined in Figure 6. Figure 6 illustrates how a plurality of wavelength pairs, all centered on the same wavelength (approximately 980 nm), are used in the algorithms. These algorithms are standard in near-IR analysis techniques and are easily programmed into suitable microprocessor circuitry by those skilled in the art. The use of these single variable term equations is highly desirable because it allows simplified instrument calibration, thereby allowing the production of low cost instruments.

The intercept constant K_o and the slope constant K_1 are initially determined for a "master unit" (which employs components similar or identical to those of the production units) by simple linear regression analyses of known samples, i.e., optical readings are obtained from the instrument being constructed for a representative number of samples which have been previously accurately analyzed via another, well-established technique, and the optical readings and previously measured percentages are utilized to calculate sets of constant values for blood glucose content using a conventional regression algorithm in a digital computer. The respective K_1 slope and K_o intercept values are then programmed into each production unit of the analyzing instrument so that each production unit can directly compute values for blood glucose from optical data readings.

Another class of usable near-IR standard algorithms involves the use of multiple regression terms. Such terms can be individual log 1/I terms or can be a multiple number of first or second derivative terms with a normalizing denominator. Such multiple terms may provide additional accuracy, but introduce much higher calibration expense which results in a more expensive instrument.

Data on a plurality of physical parameters of the body can also be utilized in conjunction with multiple wavelength measurement of near-infrared interactance, as in prior U.S. Patent No. 4,633,087, to improve the accuracy of the present blood glucose measurements.

In use, the analysis instrument 10 is positioned so that its flat bottom surface rests on the skin directly above the prominent vein of the wrist of a test subject. Light at the selected wavelengths emerging from the instrument interacts with venous blood of the subject and is detected by detector 28. Detector 28 generates an electrical signal which is processed as described above.

A key to accurate analysis is the ability of the user to locate the transmitter and detector filter (or window) directly over the prominent vein of the wrist. The location device illustrated in Figure 3 greatly facilitates this procedure. The device 50 is constructed of, e.g., a plastic material and has an overall length *L* equal to the length *L* of the analysis instrument 10 of Figure 1. Two holes 51 are present in the device and are located in the same relation as 14 and 19 in Figure 1, on midline 52, a distance *l* apart corresponding to the distance *l* of Figure 1. The holes 51 permit observation of the prominent vein. When the device is placed on the wrist and the vein is centered in each hole 51, the wrist is marked (e.g. with a felt-tipped pen) at notches 53. The location device is then removed and replaced by the analysis instrument 10 with assurance that the instrument is accurately disposed directly over the vein.

An alternate procedure for practicing the inventive method is accomplished by the use of fiber optic light probes as seen in Figure 4. These probes are connected with a known near-IR analysis instrument such as the TREBOR-70 scannnig spectrophotometer. A probe 60 is placed over the prominent vein and transmits near-IR energy of the desired wavelength(s). The near-IR energy interacts with the blood constituents and is collected by a second probe 62 placed over the vein a short distance *l* from first probe 60. A detector associ-

ated with the analytical instrument provides an electrical signal which is processed, as described above, to reveal quantitative information concerning blood glucose.

We have found that accurate quantitative analysis of blood glucose levels can be made at a variety of wavelengths with both interactance and transmittance technologies. In the embodiment illustrated in Figures 2A and 2B near-IR light energy is transmitted through the finger of the test subject and then detected by an optical detector. As in all near-IR quantitative analysis instruments, a combination of measurement wavelengths is selected which emphasizes the glucose absorption and removes the affect of interfering absorption, for example, due to water, fat and protein. Such selection is normally performed by computer search studies. Figure 7 illustrates such a search study. Figure 7 presents correlation coefficient versus wavelength for an approximated first derivative algorithm, which is not part of the present invention, and illustrates that the use of the wavelength pair of 980 ± (plus and minus) 35 nm provides a high correlation between blood glucose and absorption of near-IR energy at those two wavelengths.

An example of one embodiment of the invention uses IREDs which provide near-IR energy. Two frequencies are, respectively, equidistant above and below approximately 980 nm, i.e., they can be represented by the formula 980 ± x nm. The value of x is not critical so long as the two frequencies are centered on approximately 980 nm. For example x can be a number from 10 to 40.

Figure 8 shows that an optimum wavelength for a numerator in the first derivative division equation is approximately 1013 nm (i.e., 980 + 35 nm). Figure 9 shows that there are many wavelength regions that can provide midpoint wavelengths for use in the denominator of the first derivative division equation when the numerator utilizes 980 ± 35 nm wavelengths. Examples of such regions are seen to be from 610 to 660 nm, from 910 to 980 nm and from 990 to 1080 nm.

Figures 10 and 11 illustrate optimum center wavelengths for use in second derivative division equations. Figure 10 shows via a plot of correlation coefficient versus wavelength that the optimum numerator center frequency is approximately 1020 nm. Figure 11 shows that a denominator center frequency of about 850 nm is optimum.

As seen in Figure 2A, a near-IR probe 100 is adapted to be placed over the finger F of a test subject and in this particular embodiment includes a point source means of near-IR light energy comprised of two IREDs 116 disposed within of an upper flange 110. Each IRED is paired with a narrow bandpass optical filter 123 and is optically isolated via opaque light baffle 119. The inwardly-facing surface of flange 110 is provided with an optional optically clear window 114 for placement against the subject's finger.

Upper flange 110 is hinged about shaft 111 to lower flange 120, and a spring 112 serves to maintain the flanges in a closed position. An optical detector 128 is disposed in lower flange 120 opposite the near-IR source 116. The detector is disposed behind an optional window 129 which can be constructed of a material which is either optically clear or which excludes visible light yet permits near-IR light to pass. A finger stop 103 helps place and maintain the subject's finger in its proper position within the probe 100. Each of the flanges is provided with light-shielding barriers 113 (shown in phantom in Figure 2A) to block ambient light from entering the probe.

In this embodiment the IREDs are pulsed, i.e. energized in sequence, so that the detector 128 receives light transmitted from only one of the IREDs at any one time. This pulsed IRED technology is described in commonly owned U.S. Patent No. 4,286,327. In other similar embodiments a group of IREDs (and optional narrow bandpass filters) with identical wavelength output can be pulsed.

Probe 100 is in electrical connection with a processor unit which is schematically illustrated in Figure 2A. The processor unit houses a power source, signal amplifying, data processing and display circuitry as described in connection with the embodiment of Figure 1 and standard in near-IR analysis instrumentation.

An alternate embodiment is seen in Figure 2B. Here, probe 110 includes a single constant output IRED 116 installed behind an optional window 114. Light transmitted through the finger is gathered by optical funnel 112, which is constructed of a transparent material, and detected by multiple detectors 128. The detectors are optically isolated from one another by opaque light baffle 119. Each detector is paired with a narrow bandpass optical filter 123 and thus is set up to detect only light within the narrow wavelength range of its filter.

Near-IR point source means 116 can consist of one or more IREDs of known bandwidth and center frequency output or, as described above, can include a narrow bandpass optical filter within the light path to provide for the detection of only those wavelengths which are of interest. Multiple wavelengths can be utilized in transmission analysis and can be generated via multiple IREDs provided they are consecutively illuminated. Another approach is to use a single IRED with multiple bandpass filters which are mechanically moved through the light path as seen in Figure 5B. A third approach uses a single or group of IREDs capable of emitting a plurality of desired wavelengths with the use of multiple optical filters, each filter being married to a respective detector. Single IREDs which emit two, three or four narrow bandwidths are commercially available.

In use, the finger of the test subject is inserted between the flanges 110 of the probe 100. Near-IR light energy is emitted by the point source means, is transmitted through the finger and is detected by optical detector 128. The electrical signals produced by the detectors are transmitted via line 130 to a processor unit

where the signal is amplified and data processed (using the above algorithm) as described in connection with the apparatus of Figure 1. Blood glucose level is displayed on a readout device which preferably includes a digital display.

The accuracy of this preferred near-IR transmission embodiment can be further improved by altering the algorithm to include finger thickness as a parameter. According to Lambert's law, energy absorption is approximately proportional to the square of the thickness of the object. The thickness of the test subject's finger can be quantified by installing a potentiometer 140 between the flanges of the probe 100 as seen in Figures 2A and 2B. The output of the potentiometer, which is in electrical connection with the data processing circuitry, is indicative of finger thickness. A non-linear potentiometer can approximate the T^2 value via its output alone so that a separate squaring calculation step is not required.

Although the invention has been described in connection with certain preferred embodiments, it is not limited to them. Modifications within the scope of the following claims will be apparent to those skilled in the art. For example, accurate measurements can be obtained from parts of the body besides the wrist and the finger. The algorithm used to calculate blood constituent concentration(s) can be altered in accordance with known near-infrared analytical techniques.

Claims

1. A near-infrared quantitative analysis instrument (10;100) for non-invasive measurement of blood glucose in blood present in a body part (F) of a subject, comprising:

   (a) means (12,16,16',23;116;23';23") for introducing near-infrared energy into blood present in a body part of a subject;
   (b) a near-infrared detector (28;128) for detecting near-infrared energy emerging from the body part (F) and for providing a signal upon detection of near-infrared energy emerging from the body part;
   (c) means (50;110,111,112,120) for positioning both the near-infrared introducing means (12) and the near-infrared detector (28;128) closely adjacent to the body part so that near-infrared energy detected by the detector corresponds to blood glucose level in said body part; and
   (d) means (32,34;150) for processing the signal produced by the detector (28;128) into a second signal indicative of the quantity of glucose present in the blood of the subject;

   characterised in that the near-infrared detector (28;128) is arranged to detect infrared energy emerging from the body part (F), said near-infrared energy comprising a plurality of wavelength pairs within the range of about 600 to 1100 nanometres, said plurality of wavelength pairs being centred on the same wavelength.

2. An analysis instrument as claimed in claim 1, wherein said positioning means includes a case (20), said introducing means being disposed in a first chamber (30) of said case (20), said detector (28) being disposed in a second chamber (40) of said case (20), said case (20) having means (22) for separating the first and second chambers for preventing near-infrared energy from the introducing means from impinging directly on the detector.

3. An analysis instrument according to claim 1 or 2, wherein said introducing means includes a near-infrared energy source (16,16';116) and transmitting means (12) for transmitting said energy into the body part.

4. An analysis instrument according to claim 3, wherein said transmitting means comprises a lens (12) for focusing said infrared energy onto the body part.

5. An analysis instrument according to any one of the preceding claims, wherein said introducing means comprises at least one infrared emitting diode (16,16';116).

6. An analysis instrument according to any one of claims 1 to 5, wherein said processing means comprises amplifier means (32) for amplifying the signal provided by said detector, and data processing means (34) for converting the signal from the detector into said second signal.

7. An analysis instrument according to any one of the preceding claims, wherein a filter (23) is provided for selectively transmitting near-infrared energy, which filter is disposed between said source and said body part.

8. An analysis instrument according to any one of the preceding claims, wherein said introducing means (16,16';116) provides a bandwidth centered on about 980 nanometres.

9. An analysis instrument according to any one of the preceding claims, wherein said positioning means (50) comprises means (51,53) for marking a position for said instrument over a blood vessel of a subject.

10. An analysis instrument according to any one of claims 1 to 8, wherein said positioning means comprises means (110,111,112,120) for positioning

said introducing means (116) closely adjacent to one side of the body part and for positioning said detector (128) closely adjacent to an opposite side of the body part whereby near-infrared energy emitted by said introducing means is transmitted through said body part and detected by said detector.

11. An analysis instrument according to claim 10, further including means (140) for measuring the thickness of the body part.

12. An analysis instrument as claimed in claim 11, wherein said measuring means (140) is arranged to provide an electrical signal indicative of the thickness of the body part.

13. An analysis instrument according to claim 12, wherein said measuring means (140) comprises a variable resistor.

14. An analysis instrument according to any one of the preceding claims, wherein said said plurality of pairs of wavelengths are centred on about 980 nanometres.

15. An analysis instrument according to any one of claims 1 to 14, wherein the signal processing means (32,34;150) processes the signal according to the formula

$$C = K_0 + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

wherein C is concentration of glucose present in the blood, K_0 is an intercept constant, K_1 is line slope of

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

and $\log 1/I_G$, $\log 1/I_H$, $\log 1/I_I$ and $\log 1/I_J$ each represent an optical density value at corresponding wavelengths G, H, I and J.

16. An analysis instrument according to any one of claims 1 to 14, wherein the signal processing means (32,34;150) processes the signal according to the formula

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

wherein C is concentration of glucose present in the blood, K_0 is an intercept constant, K_1 is the line slope of

$$\frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

and $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, and $\log 1/I_F$ each represent an optical density value at corresponding wavelengths A, B, C, D, E and F.

17. A non-invasive method for quantitatively analysing blood glucose in blood of a subject, comprising:

(a) introducing near-infrared energy into blood within a body part (F) of the subject;
(b) detecting near-infrared energy emerging from the subject with a detector (28;128) which provides a signal upon detecting said energy emerging from the subject; and
(c) processing the signal to provide a second signal indicative of the amount of glucose present in the blood of the subject;

characterized in that a plurality of pairs of wavelengths of near-infrared energy within the range of about 600-1100nm are detected by said detector, said plurality of pairs of wavelengths being centered on the same wavelength.

18. A method according to claim 17, wherein said plurality of pairs of wavelengths are centered on about 980 nanometres.

19. A method according to claim 17 or 18, wherein the signal is processed according to the formula

$$C = K_0 + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

wherein C is concentration of glucose present in the blood, K_0 is an intercept constant, K_1 is line slope of

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

and $\log 1/I_G$, $\log 1/I_H$, $\log 1/I_I$, $\log 1/I_J$ each represent an optical density value at corresponding wavelengths G, H, I and J.

20. A method according to claim 17 or 18, wherein the signal is processed according to the formula

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

wherein C is concentration of glucose present in the blood, K_0 is an intercept constant, K_1 is the line

slope of

$$\frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

and $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, and $\log 1/I_F$ each represent an optical density value at corresponding wavelengths A, B, C, D, E and F.

21. A method as claimed in any one of claims 17 to 20 wherein

the near infrared energy is introduced into a vein or, artery of the subject by placing introducing means (16,16',2,23) for introducing near infrared energy closely adjacent to the vein or the artery, said near infrared energy interacting with the blood glucose of the subject and then emerging from the vein or artery; and the detector (28) is positioned close adjacent to the vein or artery and along the vein or artery a predetermined distance from the introducing means.

22. A method as claimed in any one of claims 17 to 21 comprising the steps of

marking a position for locating a quantitative analysis instrument over a vein or artery of a subject with a marking device;
aligning said instrument with said marked position, said instrument including introducing means (16, 16', 12) for introducing said near-infrared radiation into venous or arterial blood, said detector (28) for detecting near-infrared energy following interactance with blood glucose and processing means for processing the signal provided by the detector into a display indicative of blood glucose content; and
displaying results indicative of the blood glucose level based on said detected near-infrared radiation.

Patentansprüche

1. Instrument (10; 100), das im nahen Infrarot arbeitet, zur quantitativen Analyse von nicht-invasiven Messungen von Blutzucker, der in dem Blut in einem Körperteil (F) eines Wesens vorhanden ist, umfassend:

(a) Einrichtungen (12, 16, 16', 23; 116; 23'; 23") zum Einbringen der Energie des nahen Infrarots in das in einem Körperteil von einem Wesen vorhandene Blut;
(b) einen Detektor (28; 128) für nahes Infrarot zur Erfassung der von dem Körperteil (F) austretenden Energie des nahen Infrarots und zur Erzeugung eines Signals aufgrund der Erfassung der aus dem Körperteil austretenden Energie des nahen Infrarots;
(c) Einrichtungen (50; 110; 111, 112, 120) zum Positionieren sowohl der Einrichtungen (12) zum Einbringen des nahen Infrarots als auch des Detektors (28; 128) für das nahe Infrarot eng angrenzend an dem Körperteil derart, daß die von dem Detektor erfaßte Energie des nahen Infrarots dem Blutzuckerspiegel dieses Körperteils entspricht; und
(d) Einrichtungen (32, 34; 150) zum Verarbeiten des von dem Detektor (28; 128) erzeugten Signals in ein weites Signal, das die Quantität des im Blut des Wesens vorhandenen Zuckers anzeigt; **dadurch gekennzeichnet,** daß der Detektor (28; 128) für das nahe Infrarot angeordnet ist, um die aus dem Körperteil (F) austretende Infrarot-Energie zu erfassen, wobei die Energie des nahen Infrarots eine Vielzahl von Wellenlängenpaaren innerhalb eines Bereiches von etwa 600 bis 1100 Nanometer erfaßt, wobei die Vielzahl dieser Wellenlängenpaare auf die gleiche Wellenlänge zentriert sind.

2. Analyseinstrument nach Anspruch 1, worin diese Positioniereinrichtungen ein Gehäuse (20) enthalten, diese Einrichtungen zum Einbringen in einer ersten Kammer (30) von diesem Gehäuse (20) angeordnet sind, dieser Detektor (28) in einer zweiten Kammer (40) von diesem Gehäuse (20) angeordnet ist, dieses Gehäuse (20) Einrichtungen (22) aufweist, die die erste von der zweiten Kammer trennt, um zu verhindern, daß die Energie des nahen Infrarots von den Einrichtungen zum Einbringen direkt auf den Detektor auftreffen.

3. Analyseinstrument nach Anspruch 1 oder 2, worin diese Einrichtungen zum Einbringen eine Energiequelle (16, 16'; 116) für nahes Infrarot sowie Übertragungseinrichtungen (12) enthalten zum Übertragen dieser Energie in den Körperteil hinein.

4. Analyseinstrument nach Anspruch 3, worin diese Einrichtungen zum Übertragen eine Linse (12) umfassen zum Fokussieren dieser Infrarot-Energie auf den Körperteil.

5. Analyseinstrument nach irgend einem der vorstehenden Ansprüche, worin diese Einrichtungen zum Einbringen zumindest eine Infrarot emittierende Diode (16, 16'; 116) enthalten.

6. Analyseinstrument nach irgend einem der Ansprüche 1 bis 5, worin diese Einrichtungen zum Verarbeiten eine Verstärkereinrichtung (32) umfaßt zum

Verstärken des von diesem Detektor zur Verfügung gestellten Signals, sowie Datenverarbeitungseinrichtungen (34) enthält zum Konvertieren des Signals von dem Detektor in dieses zweite Signal.

7. Analyseinstrument nach irgend einem der vorstehenden Ansprüche, worin ein Filter (23) vorgesehen ist zum selektiven Übertragen der Energie des nahen Infrarots, wobei dieses Filter zwischen dieser Quelle und diesem Körperteil angeordnet ist.

8. Analyseinstrument nach irgend einem der vorstehenden Ansprüche, worin diese Einrichtungen (16, 16'; 116) zum Einbringen eine Bandbreite zur Verfügung stellt, die um etwa 980 Nanometer zentriert ist.

9. Analyseinstrument nach irgend einem der vorstehenden Ansprüche, worin diese Einrichtungen (50) zum Positionieren Einrichtungen (51, 53) umfassen zum Markieren einer Position für dieses Instrument über einem Blutgefäß von einem Wesen.

10. Analyseinstrument nach irgend einem der Ansprüche 1 bis 8, worin diese Einrichtungen zum Positionieren Einrichtungen (110, 111, 112, 120) umfaßt, um diese Einrichtungen zum Einbringen nahe an einer Seite des Körperteils angrenzend zu positionieren, und um diesen Detektor (128) nahe an einer entgegengesetzten Seite des Körperteils zu positionieren, wodurch die von den Einrichtungen zum Einbringen abgegebene Energie des nahen Infrarots durch diesen Körperteil hindurch übertragen und von diesem Detektor erfaßt wird.

11. Analyseinstrument nach Anspruch 10, des weiteren Einrichtungen (140) enthaltend zur Messung der Dicke des Körperteils.

12. Analyseinstrument nach Anspruch 11, worin diese Einrichtungen (140) zum Messen angeordnet sind, um ein elektrisches Signal zu erzeugen, das die Dicke des Körperteils anzeigt.

13. Analyseinstrument nach Anspruch 12, worin diese Einrichtungen (140) zum Messen einen variablen Widerstand umfassen.

14. Analyseinstrument nach irgend einem der vorstehenden Ansprüche, worin diese Vielzahl von Paaren der Wellenlängen um etwa 980 Nanometer zentriert sind.

15. Analyseinstrument nach einem der Ansprüche 1 bis 14, worin die Einrichtungen (32, 34; 150) zum Verarbeiten der Signale das Signal gemäß folgender Formel berechnen:

$$C = K_o + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

worin C die Konzentration des in dem Blut vorhandenen Zuckers ist, K_0 eine Intercept-Konstante ist, K_1 die Linienneigung ist von

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

und $\log 1/I_G$, $\log 1/I_H$, $\log 1/I_I$ und $\log 1/I_J$ jeweils einen optischen Dichtewert bei den entsprechenden Wellenlängen G, H, I und J repräsentieren.

16. Anlayseinstrument nach irgend einem der Ansprüche 1 bis 14, worin die Einrichtungen (32, 34; 150) zum Verarbeiten der Signale das Signal gemäß folgender Formel verarbeiten:

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2\log 1/I_E + \log 1/I_F]}$$

worin C die Konzentration von in dem Blut vorhandenen Zucker ist, K_0 eine Intercept-Konstante ist, K_1 die Linienneigung ist von

$$\frac{[\log 1/I_A - 2\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2\log 1/I_E + \log 1/I_F]}$$

und wobei $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, und $\log 1/I_F$ jeweils einen optischen Dichtewert bei den entsprechenden Wellenlängen A, B, C, D, E und F repräsentieren.

17. Nicht-invasives Verfahren zur quanititativen Analyse des Blutzuckers im Blut eines Wesens, mit den Verfahrensschritten:

(a) Einbringen einer Energie des nahen Infrarots in das Blut innerhalb eines Körperteils (F) eines Wesens;
(b) Erfassen der aus dem Wesen heraustretenden Energie des nahen Infrarots mit einem Detektor (28; 128), der durch das Erfassen dieser aus dem Wesen austretenden Energie ein Signal erzeugt, und
(c) Verarbeiten des Signals, um ein zweites Signal zu erzeugen, das die Menge des in dem Blut des Wesens vorhandenen Zuckers anzeigt;

dadurch gekennzeichnet, daß eine Vielzahl von Paaren von Wellenlängen der Energie des nahen Infrarots innerhalb des Bereichs von etwa 600-1100

nm von diesem Detektor erfaßt werden, wobei die Vielzahl dieser Paare von Wellenlängen um die gleiche Wellenlänge zentriert sind.

18. Verfahren nach Anspruch 17, worin diese Vielzahl von Paaren von Wellenlängen um etwa 980 Nanometer zentriert sind.

19. Verfahren nach Anspruch 17 oder 18, worin das Signal gemäß der folgenden Formel verarbeitet wird

$$C = K_o + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

worin C die Konzentration des in dem Blut vorhandenen Zuckers ist, K_0 eine intercept-Konstante ist, K_1 die Linienneigung ist von

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

und $\log 1/I_G$, $\log 1/I_H$, $\log 1/I_I$ und $\log 1/I_J$ jeweils einen optischen Dichtewert bei den entsprechenden Wellenlängen G, H, I und J repräsentieren.

20. Verfahren nach Anspruch 17 oder 18, worin das Signal gemäß folgender Formel verarbeitet wird

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2\log 1/I_E + \log 1/I_C]}{[\log 1/I_D - 2\log 1/I_E + \log 1/I_F]}$$

worin C die Konzentration von in dem Blut vorhandenen Zucker ist, K_0 eine intercept-Konstante ist, K_1 die Linienneigung ist von

$$\frac{[\log 1/I_A - 2\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2\log 1/I_E + \log 1/I_F]}$$

und wobei $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, und $\log 1/I_F$ jeweils einen optischen Dichtewert bei den entsprechenden Wellenlängen A, B, C, D, E und F repräsentieren.

21. Verfahren nach irgend einem der Ansprüche 17 bis 20, worin die Energie des nahen Infrarots in eine Vene oder eine Arterie des Wesens eingebracht wird durch Plazieren von Einrichtungen (16, 16', 2, 23) zum Einbringen der Energie des nahen Infrarots eng an der Vene oder an der Arterie angrenzend, wobei diese Energie des nahen Infrarots mit dem Blutzucker des Wesens interagiert und anschließend aus der Vene oder aus der Arterie austritt; und worin der Detektor (28) nahe an der Vene oder an der Arterie angrenzend sowie entlang der Vene oder der Arterie mit einer vorbestimmten Distanz zu den Einrichtungen zum Einbringen angeordnet ist.

22. Verfahren nach irgend einem der Ansprüche 17 bis 21, mit den Verfahrensschritten

Markieren einer Position mit einer Markierungsvorrichtung, um ein Instrument zur quantitativen Analyse über einer Vene oder einer Arterie des Wesens zu positionieren;
Ausrichten dieses Instruments mit dieser markierten Position, wobei dieses Instrument Einrichtungen (16, 16', 12) zum Eindringen dieser Strahlung des nahen Infrarots in das venöse oder arterielle Blut enthält, diesen Detektor (28) aufweist zur Erfassung der Energie des nahen Infrarots, die der Interaktion mit dem Blutzucker folgt, sowie Verarbeitungseinrichtungen aufweist zum Verarbeiten des von dem Detektor erzeugten Signals in eine Anzeige, die den Blutzuckergehalt darstellt; und
Anzeigen der Ergebnisse, die den Blutzuckerspiegel auf der Basis dieser erfaßten Strahlung des nahen Infrarots darstellt.

Revendications

1. Instrument (10 ; 100) d'analyse quantitative dans le proche infrarouge pour une mesure non invasive du glucose sanguin présent dans le sang d'une partie (F) du corps d'un sujet, comprenant :

(a) des moyens (12, 16, 16', 23 ; 116 ; 23' ; 23") pour introduire une énergie dans le proche infrarouge dans le sang présent dans une partie du corps d'un sujet;
(b) un détecteur (28 ; 128) dans le proche infrarouge pour détecter l'énergie dans le proche infrarouge émergeant de la partie (F) du corps et pour fournir un signal lors de la détection de l'énergie dans le proche infrarouge émergeant de la partie du corps;
(c) des moyens (50 ; 110, 111, 112, 120) pour positionner à la fois les moyens (12) d'introduction dans le proche infrarouge et le détecteur (28 ; 128) dans le proche infrarouge adjacents de façon très proche de la partie du corps de sorte que l'énergie dans le proche infrarouge détectée par le détecteur corresponde au niveau du glucose sanguin dans ladite partie du corps ; et
(d) des moyens (32, 34 ; 150) pour traiter le signal produit par le détecteur (28 ; 128) en un second signal indicateur de la quantité de glucose présent dans le sang du sujet ;
caractérisé en ce que le détecteur (28 ;

128) dans le proche infrarouge est disposé de façon à détecter l'énergie infrarouge émergeant de la partie (F) du corps, ladite énergie dans le proche infrarouge comprenant une pluralité de paires de longueurs d'onde situées dans la plage d'environ 600 à 1100 nanomètres, ladite pluralité de paires de longueurs d'onde étant centrées sur la même longueur d'onde.

2. Instrument d'analyse selon la revendication 1, dans lequel lesdits moyens de positionnement comprennent un boîtier (20), lesdits moyens d'introduction étant disposés dans une première chambre (30) dudit boîtier, ledit détecteur (28) étant disposé dans une seconde chambre (40) dudit boîtier (20), ledit boîtier (20) comprenant des moyens (22) pour séparer la première et la seconde chambres de façon à empêcher que l'énergie dans le proche infrarouge provenant desdits moyens d'introduction vienne frapper directement le détecteur.

3. Instrument d'analyse selon la revendication 1 ou la revendication 2, dans lequel lesdits moyens d'introduction comprennent une source d'énergie dans le proche infrarouge (16, 16' ; 116) et des moyens de transmission (12) pour transmettre ladite énergie à l'intérieur de la partie du corps.

4. Instrument d'analyse selon la revendication 3, dans lequel lesdits moyens de transmission comprennent une lentille (12) pour focaliser ladite énergie infrarouge sur la partie du corps.

5. Instrument d'analyse selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens d'introduction comprennent au moins une diode émettrice infrarouge (16, 16' ; 116).

6. Instrument d'analyse selon l'une quelconque des revendications 1 à 5, dans lequel lesdits moyens de traitement comprennent des moyens amplificateurs (32) pour amplifier le signal fourni par ledit détecteur, et des moyens de traitement de données (34) pour convertir le signal provenant du détecteur en ledit second signal.

7. Instrument d'analyse selon l'une quelconque des revendications précédentes, dans lequel un filtre (23) est prévu pour transmettre sélectivement l'énergie dans le proche infrarouge, lequel filtre est disposé entre ladite source et ladite partie du corps.

8. Instrument d'analyse selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens d'introduction (16, 16' ; 116) fournissent une largeur de bande centrée sur environ 980 nanomètres.

9. Instrument d'analyse selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de positionnement (50) comprennent des moyens (51, 53) pour marquer une position pour ledit instrument par dessus un vaisseau sanguin d'un sujet.

10. Instrument d'analyse selon l'une quelconque des revendications 1 à 8, dans lequel lesdits moyens de positionnement comprennent des moyens (110, 111, 112, 120) pour positionner lesdits moyens d'introduction (116) adjacents de façon très proche à l'un des côtés d'une partie du corps et pour positionner ledit détecteur (128) adjacent très proche d'un côté opposé de la partie du corps, grâce à quoi l'énergie dans le proche infrarouge émise par lesdits moyens d'introduction est transmise à travers ladite partie du corps et est détectée par ledit détecteur.

11. Instrument d'analyse selon la revendication 10, comprenant en outre des moyens (140) pour mesurer l'épaisseur de la partie du corps.

12. Instrument d'analyse selon la revendication 11, dans lequel lesdits moyens de mesure (140) sont disposés de façon à fournir un signal électrique indicateur de l'épaisseur de la partie du corps.

13. Instrument d'analyse selon la revendication 12, dans lequel lesdits moyens de mesure (140) comprennent une résistance variable.

14. Instrument d'analyse selon l'une quelconque des revendications précédentes dans lequel ladite pluralité des paires de longueurs d'onde sont centrées sur environ 980 nanomètres.

15. Instrument d'analyse selon l'une quelconque des revendications 1 à 14, dans lequel les moyens de traitement du signal (32, 34; 150) traitent le signal selon la formule

$$C = K_0 + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

dans laquelle C est la concentration du glucose présent dans le sang, K_0 est une constante d'interception, k_1 est la pente de la droite

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

et $\log 1/I_G$, $\log 1/I_H$, $\log 1/I_I$ et $\log 1/I_J$, représentent chacun une valeur de densité optique sous les longueurs d'onde correspondantes G, H, I et J.

16. Instrument d'analyse selon l'une quelconque des revendications 1 à 14, dans laquelle les moyens de traitement du signal (32, 34 ; 150) traitent le signal en conformité avec la formule

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

dans laquelle C est la concentration de glucose présent dans le sang, K_0 est une constante d'interception, K_1 est la pente de la droite

$$\frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

et $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, et $\log 1/I_F$ représentent chacun une valeur de densité optique sous les longueurs d'onde correspondantes A, B, C, D, E et F.

17. Un procédé non invasif pour l'analyse quantitative du glucose sanguin contenu dans le sang d'un sujet, comprenant :

(a) l'introduction d'une énergie dans le proche infrarouge dans le sang contenu à l'intérieur d'une partie (F) du corps du sujet;
(b) la détection de l'énergie dans le proche infrarouge émergeant du sujet au moyen d'un détecteur (28 ; 128) qui fournit un signal lors de la détection de ladite énergie émergeant du sujet ; et
(d) le traitement du signal pour fournir un second signal indicateur de la quantité du glucose présent dans le sang du sujet;

caractérisé en ce qu'on détecte au moyen dudit détecteur une pluralité de paires de longueurs d'onde d'énergie dans le proche infrarouge à l'intérieur de la plage comprise entre environ 600 et 1100 nm, ladite pluralité de paires de longueurs d'ondes étant centrées sur la même longueur d'onde.

18. Procédé selon la revendication 17, dans lequel ladite pluralité de paires de longueurs d'onde sont centrées sur environ 980 nanomètres.

19. Procédé selon la revendication 17 ou 18, dans lequel le signal est traité selon la formule

$$C = K_0 + K_1 \frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

dans laquelle C est la concentration de glucose présent dans le sang, K_0 est une constante d'interception, K_1 est la pente de la droite

$$\frac{[\log 1/I_G - \log 1/I_H]}{[\log 1/I_I - \log 1/I_J]}$$

et log de $1/I_G$, log de $1/I_H$, log de $1/I_I$, log de $1/I_J$ représentent chacun une valeur de densité optique sous les longueurs d'onde correspondantes G, H, I et J.

20. Procédé conforme à la revendication 17 ou 18, dans lequel le signal est traité conformément à la formule

$$C = K_0 + K_1 \frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

dans laquelle C est la concentration de glucose présent dans le sang, K_0 est une constante d'interception, K_1 est la pente de la droite

$$\frac{[\log 1/I_A - 2^*\log 1/I_B + \log 1/I_C]}{[\log 1/I_D - 2^*\log 1/I_E + \log 1/I_F]}$$

et $\log 1/I_A$, $\log 1/I_B$, $\log 1/I_C$, $\log 1/I_D$, $\log 1/I_E$, et $\log 1/I_F$ représentent chacun une valeur de densité optique sous les longueurs d'onde correspondantes A, B, C, D, E et F.

21. Procédé selon l'une quelconque des revendications 17 à 20, dans lequel l'énergie dans le proche infrarouge est introduite dans une veine ou dans une artère du sujet en plaçant les moyens d'introduction (16, 16', 2, 23) pour introduire une énergie dans le proche infrarouge adjacents de façon très proche de la veine de l'artère, ladite énergie dans le proche infrarouge interagissant avec le glucose du sang du sujet, et émergeant alors de la veine ou de l'artère ; et

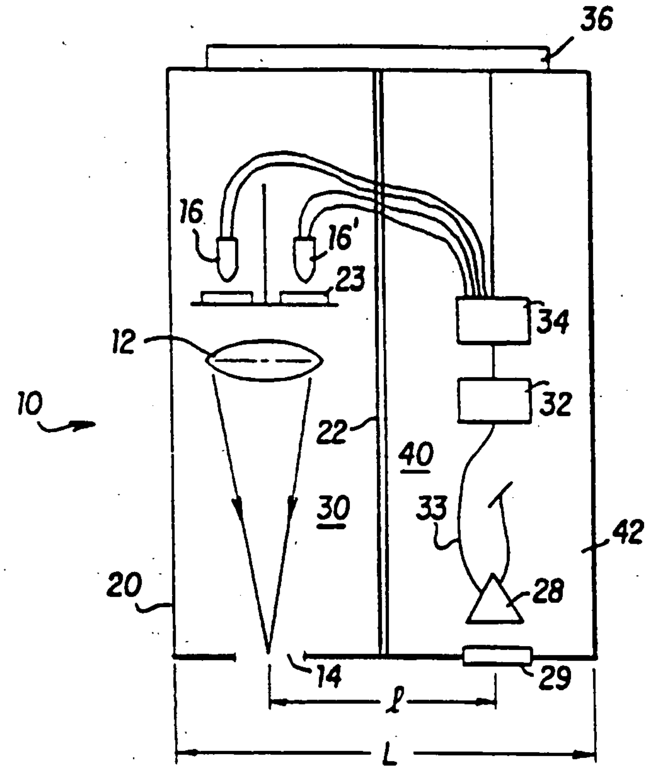
on positionne le détecteur (28) adjacent très proche de la veine ou de l'artère et le long de la veine ou de l'artère à une distance prédéterminée des moyens d'introduction.

22. Procédé selon l'une quelconque des revendications 17 à 21, comprenant les étapes consistant à :

marquer une position pour localiser un instrument d'analyse quantitative par dessus une veine ou une artère d'un sujet au moyen d'un dispositif de marquage,
aligner ledit instrument avec ladite position marquée, ledit instrument comprenant des moyens d'introduction (16, 16', 12) pour introduire ledit rayonnement dans le proche infra-

rouge à l'intérieur du sang de la veine ou de l'artère, ledit détecteur (28) pour détecter l'énergie dans le proche infrarouge suivant l'inter-réaction avec le glucose du sang, et des moyens de traitement pour traiter le signal fourni par le détecteur dans un dispositif d'affichage indiquant la teneur du glucose du sang ; et

afficher les résultats indiquant le niveau du glucose du sang en se fondant sur ledit rayonnement détecté dans le proche infrarouge.


36
16
16'
23
34
12
32
10
22
40
30
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42
28
20
14
29
ℓ
L

FIG. 1

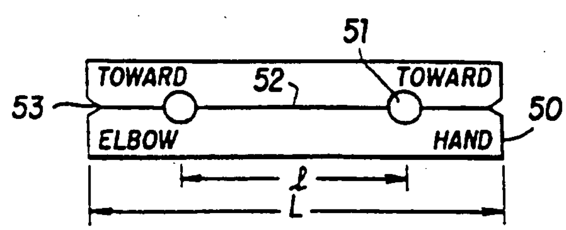
51
TOWARD
52
TOWARD
53
50
ELBOW
HAND
ℓ
L

FIG. 3

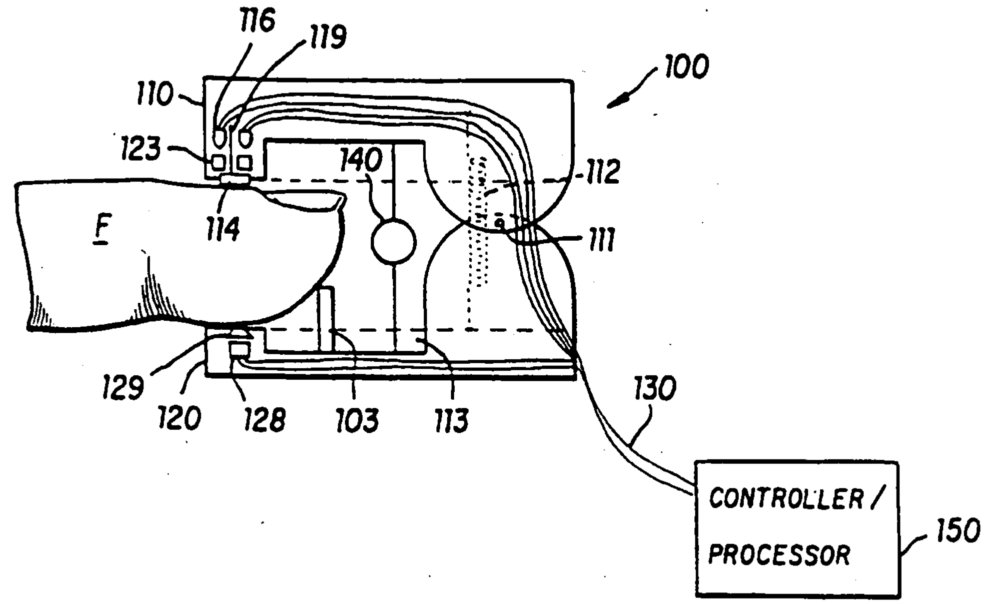
116
119
100
110
123
140
112
F
114
111
129
120
128
103
113
130
CONTROLLER / PROCESSOR
150

FIG. 2A

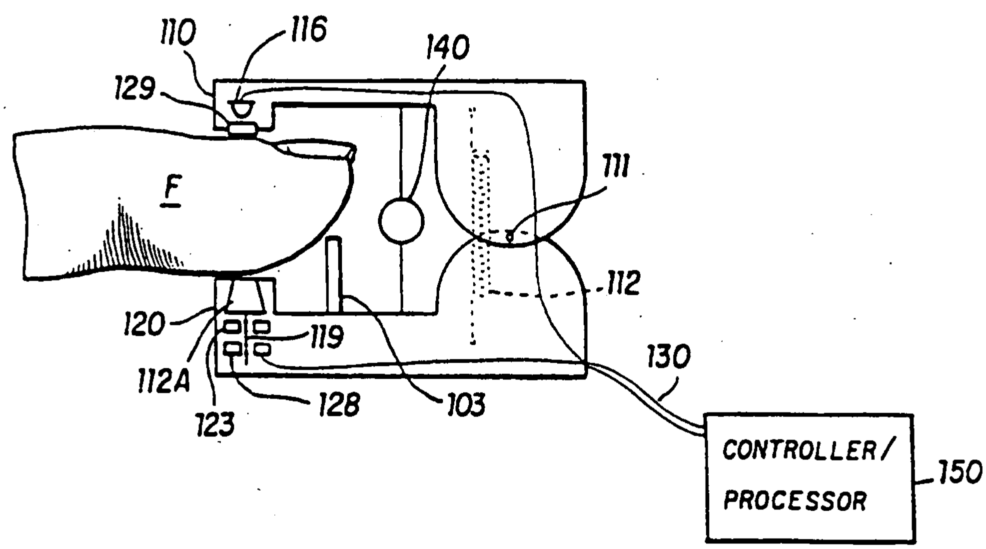
110
116
140
129
F
111
112
120
119
112A
130
123
128
103
CONTROLLER / PROCESSOR
150

FIG. 2B

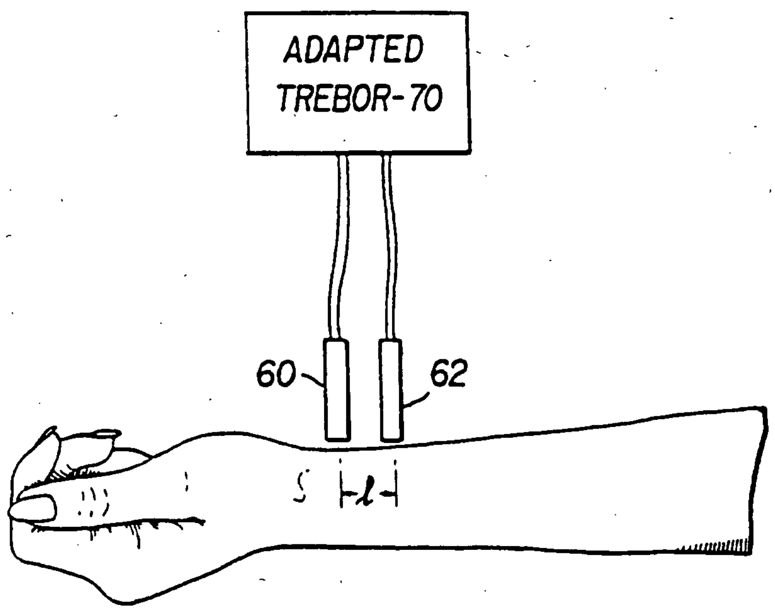

FIG. 4

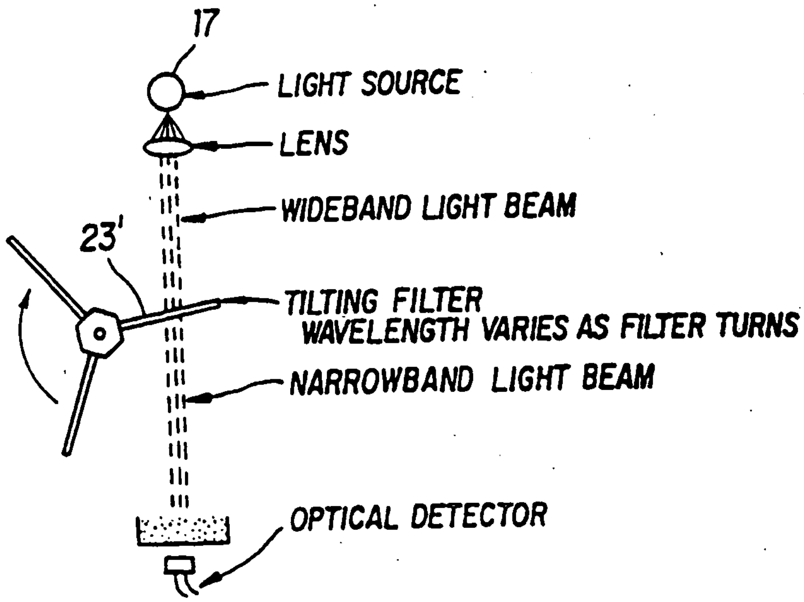
17
LIGHT SOURCE
LENS
WIDEBAND LIGHT BEAM
23'
TILTING FILTER
WAVELENGTH VARIES AS FILTER TURNS
NARROWBAND LIGHT BEAM
OPTICAL DETECTOR

FIG. 5A

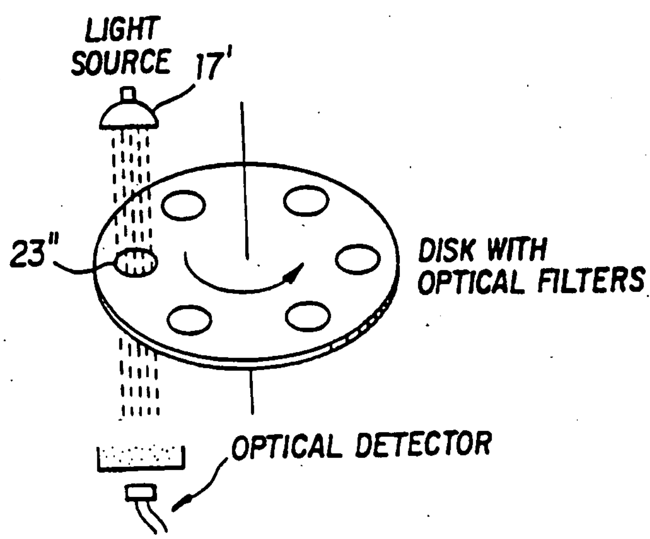
LIGHT SOURCE
17'
23"
DISK WITH OPTICAL FILTERS
OPTICAL DETECTOR

FIG. 5B

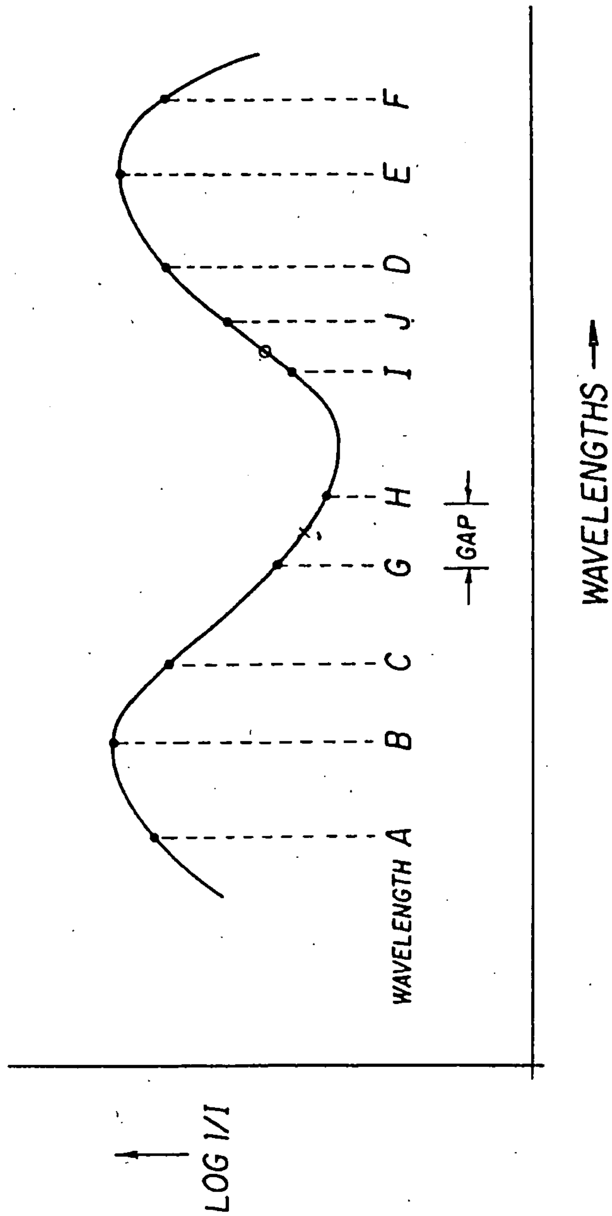

FIG. 6

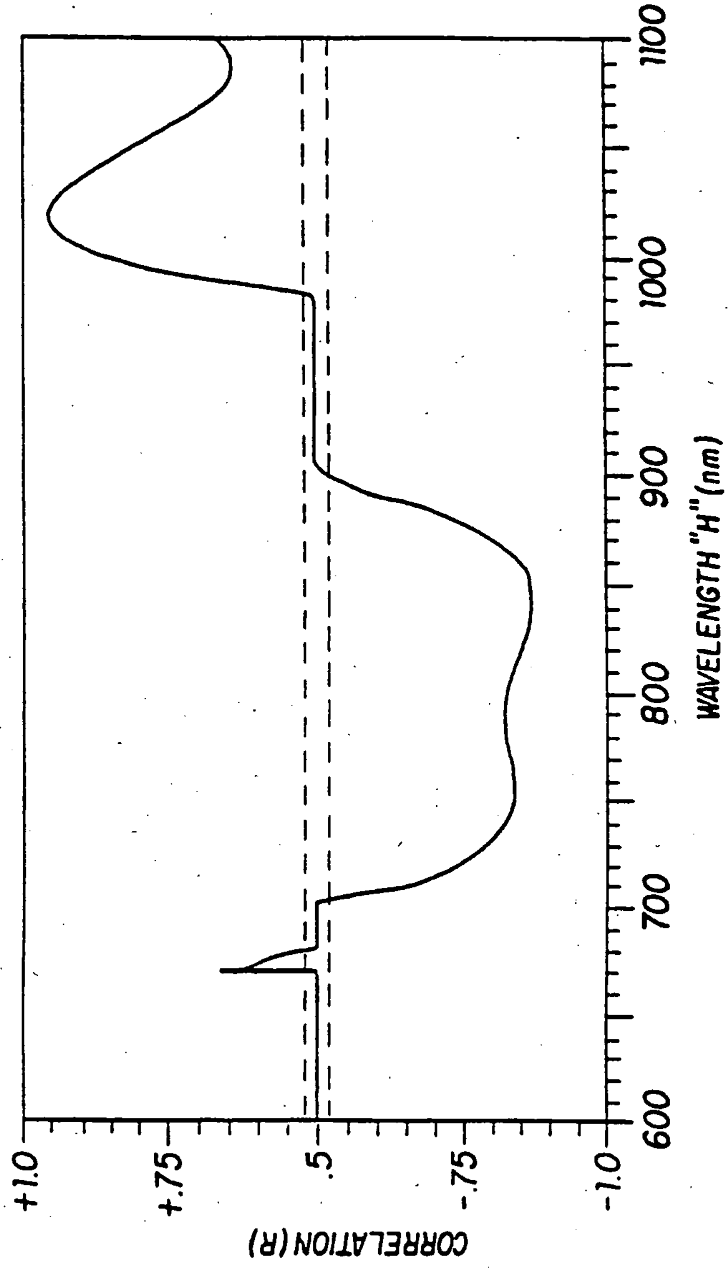
+1.0
+.75
.5
-.75
-1.0
CORRELATION (R)
600
700
800
900
1000
1100
WAVELENGTH "H" (nm)

FIG. 7

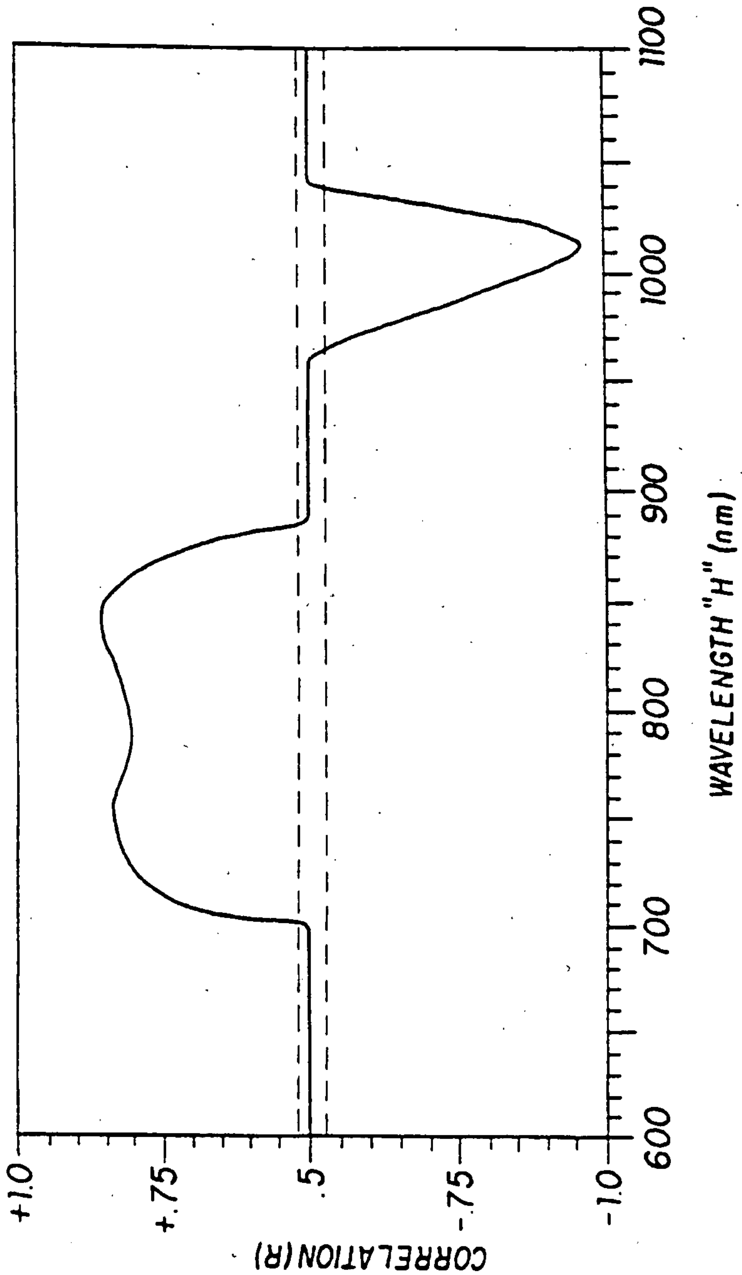
+1.0
+.75
.5
-.75
-1.0
CORRELATION (R)
600
700
800
900
1000
1100
WAVELENGTH "H" (nm)

FIG. 8

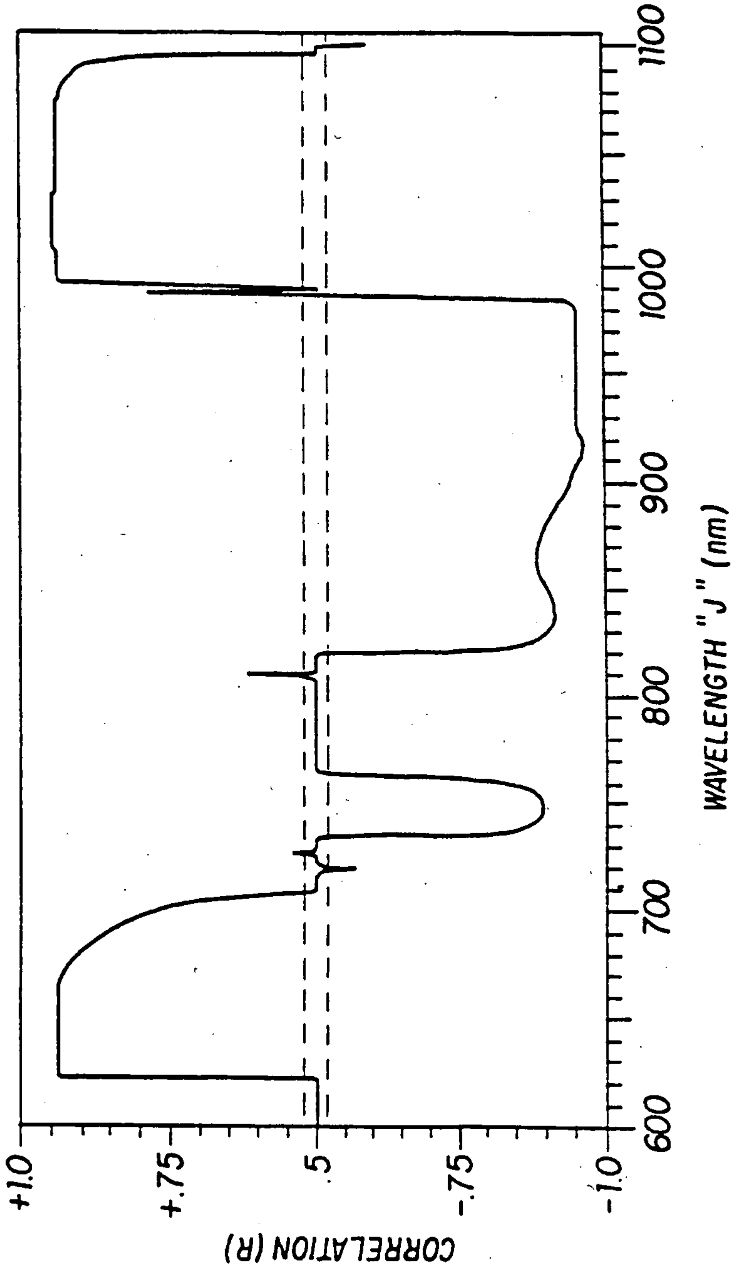
+1.0
+.75
.5
-.75
-1.0
CORRELATION (R)
600
700
800
900
1000
1100
WAVELENGTH "J" (nm)

FIG. 9

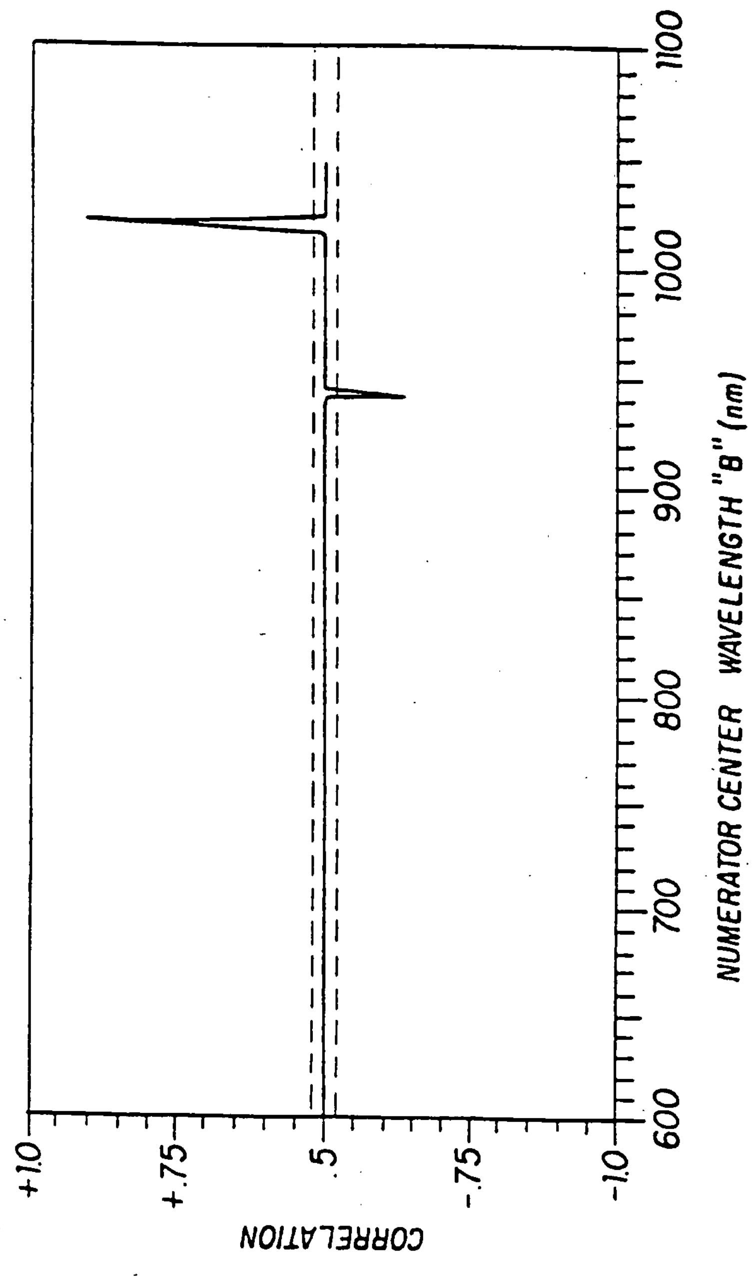
+1.0
+.75
.5
-.75
-1.0
CORRELATION
600
700
800
900
1000
1100
NUMERATOR CENTER WAVELENGTH "B" (nm)

FIG. 10

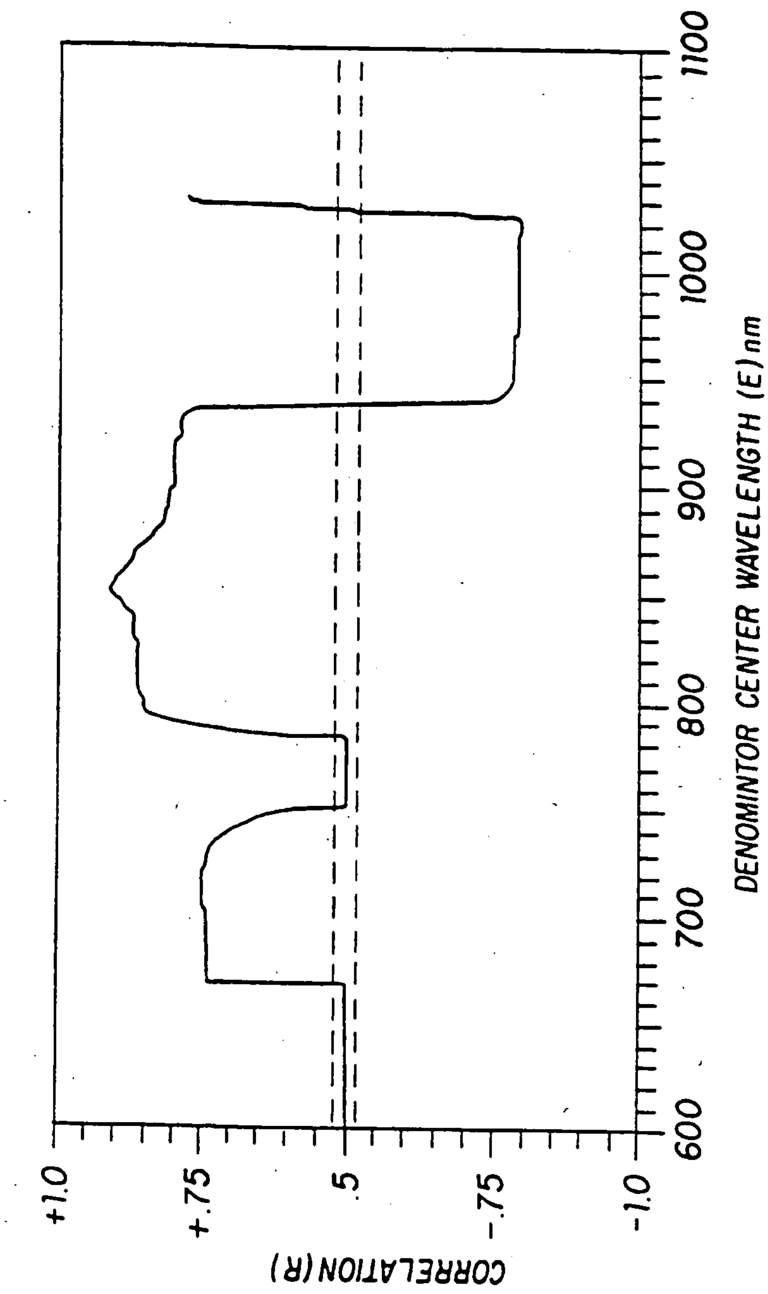
+1.0
+.75
.5
-.75
-1.0
CORRELATION (R)
600
700
800
900
1000
1100
DENOMINTOR CENTER WAVELENGTH (E) nm

FIG. 11